USE OF THE HOT WIRE ANEMOMETER TO LOCATE FROTH LEVELS

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PREFACE

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CHAPTER I

THE PROBLEM

A factor that is of great importance in contacting equipment containing vapor-liquid systems is froth formation. Examples of this type of equipment are the bubble cap column and the perforated tray column. Froth is formed as the vapor rises through the liquid. Until now, there has been no accurate method for locating the froth level above a tray. The purpose of this investigation was to determine whether or not the hot wire anemometer could be used as an instrument for this purpose. Since it was useful, an investigation was also made to determine if the hot wire anemometer could be used to determine densities at various points in the froth bed.

The primary purpose of vapor-liquid columns is to provide a high degree of mechanical mixing between the vapor and liquid phases. This mixing allows diffusion, absorption, chemical reaction, or chemical equilibrium between the two phases. The mixing of the phases forms a large area of interface between the two phases. Froth formation is important because it forms a greater amount of interface between the two phases. This additional interface affects the operating characteristics of the equipment. Froth formation may also cause some of the liquid on a tray to be entrained in the gas phase and carried to the tray above. This will also affect the operation of the equipment.

At present, the only methods of location to find the froth level in operating equipment are insertion of a hand through an inspection port and visual observation through inspection ports. Both of these methods result in a poor degree of accuracy and, thereby, a poor evaluation of the operating characteristics of the equipment.

Limitations

In this investigation, only air and water were used with a single tray column. The tray was a perforated plate type. Only one type of anemometer was tested. No attempt was made to evaluate different types of anemometer construction. The precision of measurements in this investigation was fairly high, generally to three significant figures. More precise measurements could be made by using more complex electrical equipment.

Primary difficulties encountered in this work were the design and manufacture of the hot wire anemometer and adjustment of the equipment to give sufficient accuracy without becoming overly sensitive to small changes in the density of the froth bed.

Clarification of Terms

Froth is used to denote any formation of bubbles or foam over that to be expected from the amount of liquid present and the volume of gas flowing through the liquid at any given time.

Froth bed is used to signify the entire mixture of liquid and vapor above the tray.

CHAPTER II

REVIEW OF THE LITERATURE

Historical Background

The general problem of locating liquid levels and measuring densities has recieved much attention in past work. The majority of this work was done with stationary systems or with systems in which a sharp interface and a sharp density change are present. The problem of locating froth levels and measuring densities through a froth bed in a dynamic system resulted from a constantly increasing use of vapor-liquid contacting equipment of the type that has been previously described. This equipment utilizes the physical advantage of vapor or gas rising through a liquid in order to achieve a high degree of mechanical mixing between the two phases. The theoretical design methods for these types of equipment do not contain any correction for froth formation. It was pointed out that froth formation increases the amount of interface available for the desired reaction between phases. Since the design methods do not consider froth formation, they are sometimes highly inaccurate in predicting the performance of the finished equipment. Froth formation also makes evaluation of the performance of operating equipment difficult.

In order to properly evaluate the effect of froth formation in equipment, experimental data as to exactly what occurs in the froth bed must be developed. This type of research has been delayed by the lack of an instrument to accurately locate froth levels. The work has also been delayed by the lack of an instrument to measure point to point densities through the froth bed. It was the purpose of this work to develop such an instrument. The instrument investigated was the hot wire anemometer.

The Hot Wire Anemometer

The hot wire anemometer is also called a resistance thermometer. The basic principle of the anemometer is the change of the resistance of a wire with a change in the temperature of the wire. There are two classes of applications of the anemometer. In one, the wire is maintained at a constant temperature by a suitable electrical circuit and the temperature of the surroundings is measured by the rate of heat loss from the wire. In the other class of applications, the wire temperature is allowed to vary with the temperature of its surroundings and the change of resistance of the wire is measured by use of a Wheatstone electrical bridge circuit. It is the latter method of application that was used in this work.

Froth Measurement

Since the necessity of proper measurement of froth heights has been recognized only recently, there is little background of literature on this subject. In the only available reference to work of this type, the froth heights were measured by inserting a hand through an inspection port. This reference was the Third Annual Progress Report by a committee of the American Institute of Chemical Engineers which has been working on tray efficiencies in distillation columns.

In work done by Mr. Davis in England in 1920, the hot wire anemometer was used to measure convected heat in air. His work led to this mathematical expression:

$$Q = A\sqrt{\rho v} + B$$

where Q is the rate of heat loss from the wire

ρ is the density of the air

v is the velocity of the air past the wire

A and B are constants.

CHAPTER III

METHODS AND PROCEDURE

Equipment

The equipment consisted of a 4 inch internal diameter glass and plastic column. In the column was a single perforated plate type tray. Into the top of the column was inserted a probe carrying the hot wire anemometer. Necessary instrumentation equipment was attached to the column. A general schematic sketch of the equipment is shown in Figure 1. A circuit diagram of the electrical circuit used is shown in Figure 2.

The equipment used was:

1. Air Supply - An air source of 80 to 120 pounds per square inch was available. The air flow was controlled by means of the valve on an air pressure regulator.
2. Ammeter - The ammeter used was a Weston Company Model 280-DC direct current ammeter. Its scale was graduated from 0 to 500 milliamperes with divisions each 5 milliamperes.
3. Batteries - One and one-half volt dry cell batteries were used.
4. Column - The column was composed of four sections - three glass and one plastic. These sections were held together with clamps. There were two glass sections over

the plastic section and one glass section under it. Each section was six inches high and had an internal diameter of four inches. Rubber gaskets were placed between the sections as they were assembled. The tray was placed immediately above the plastic section and had rubber gaskets on each side of it. Inside the column, against the side, was placed a section of meter stick with the bottom resting on the tray and the top against the top plate of the column. The reading of 52.0 centimeters was that at the bottom of the stick with the readings increasing towards the top of the stick.

The top plate of the column was made of one-quarter inch plexiglass plastic. In the center was drilled a three-quarters inch hole. Glued to the top of the plate and centered about the hole was a section of rigid styrene plastic tubing with an external diameter of three-quarters of an inch. This piece of tubing was the mount for the probe. In the tubing was placed a set screw to hold the probe in place. On the bottom of the plate below the center hole was a sheet of rubber with a circular hole in it of slightly less than one-half inch diameter. This was held in place with a sheet of one-sixteenths inch aluminum and four screws. This assembly was the sealing gasket for the probe. About one and one-quarter inches from the center of the plate and equally spaced were drilled four more holes. Two of them were one-half inch holes. One was for the thermometer and the

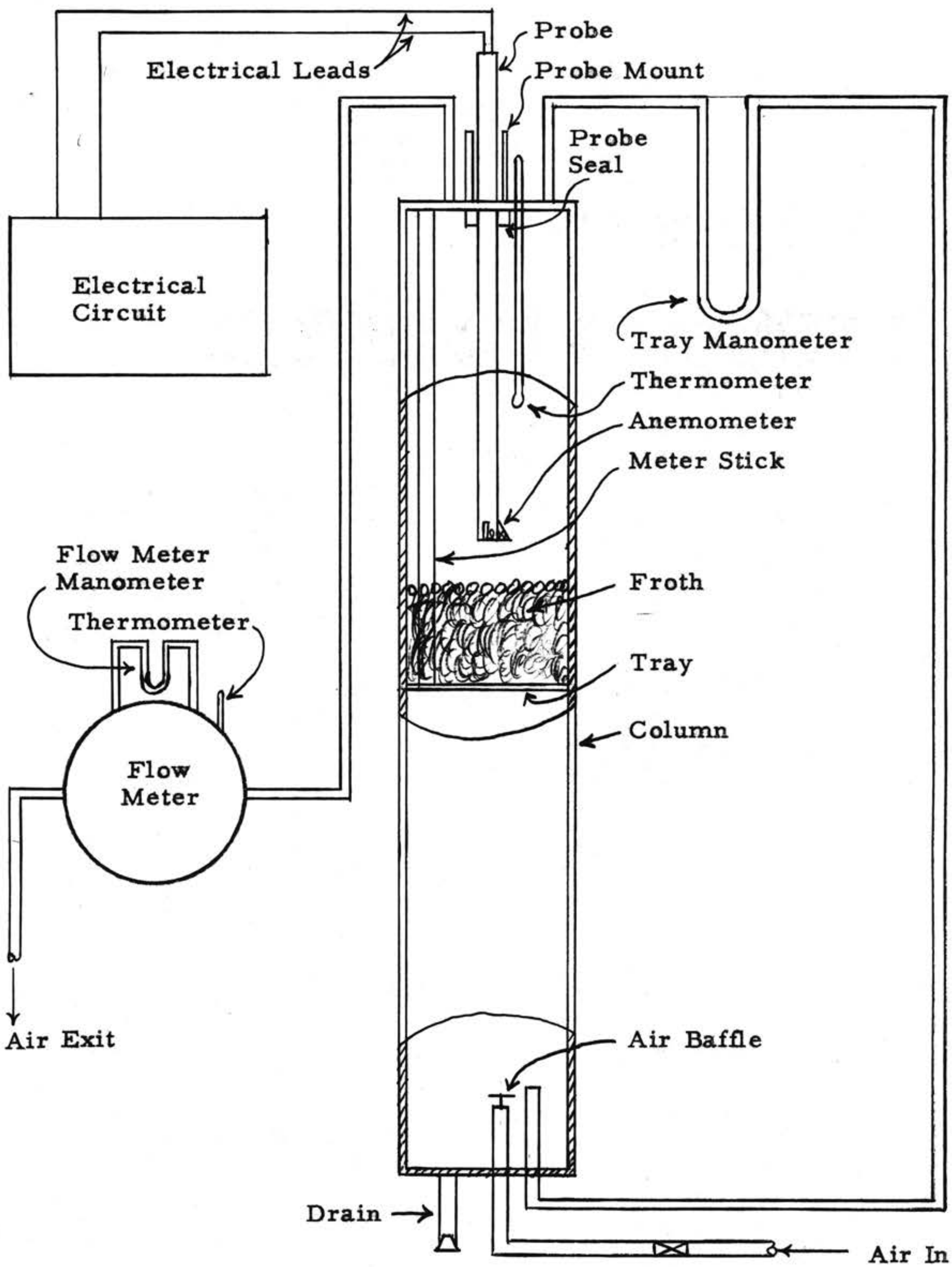


Figure 1
FLOW SHEET AND DIAGRAM OF EXPERIMENTAL APPARATUS

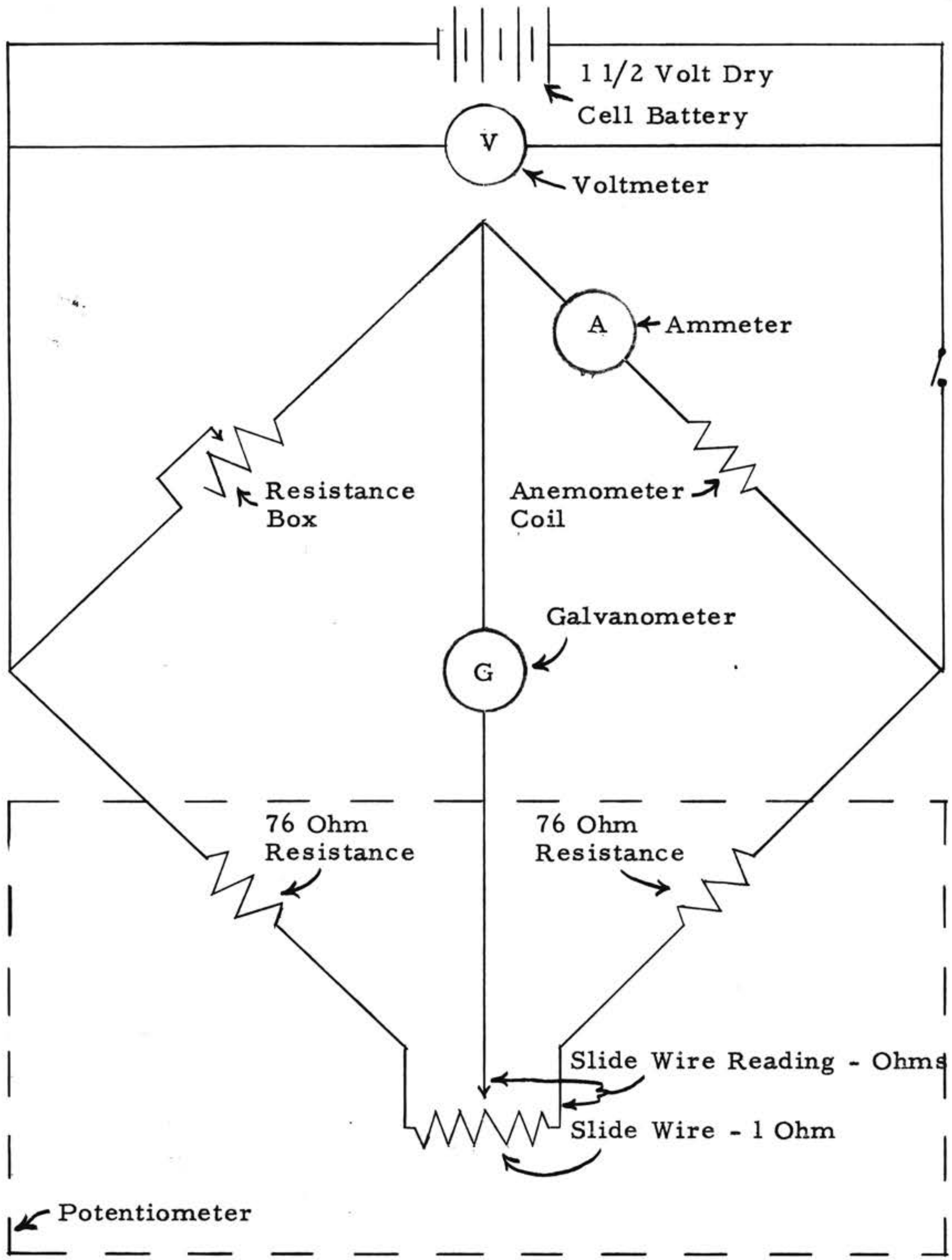
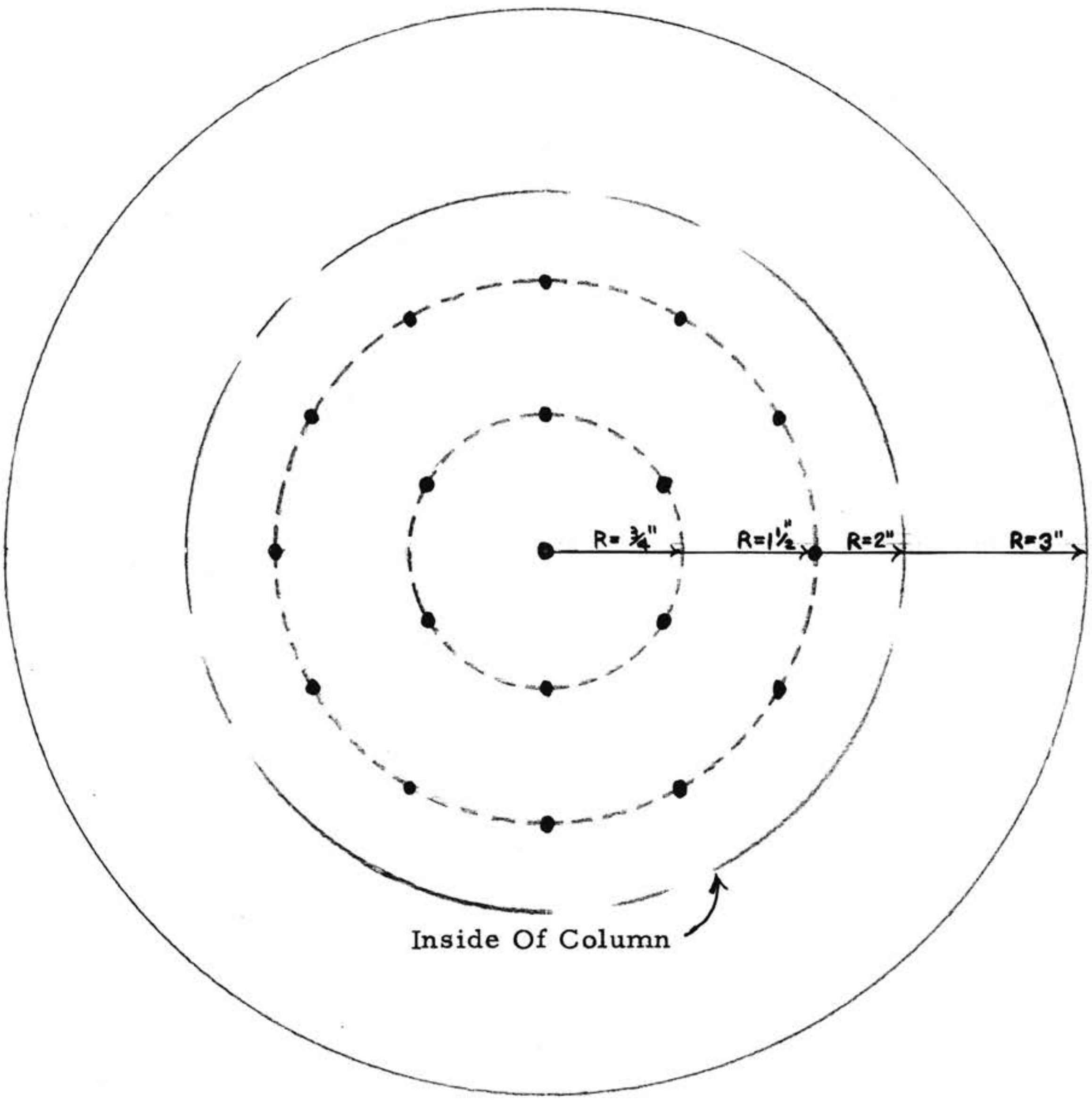


Figure 2

ELECTRICAL CIRCUIT DIAGRAM



Each hole was 1/16 inch in diameter and was undercut 1/32 inch to a diameter of 3/32 inch.
The tray was made of 1/16 inch aluminum.

Figure 3

DESIGN OF TRAY

other was for filling the column with the desired amount of water. The other two holes were tapped and adapters for one-quarter inch copper tubing were inserted. One hole was the air exit and the other was a pressure tap for the manometer.

The bottom plate of the column was made of one-sixteenth inch aluminum sheet. Off center on one side of it was brazed a piece of one-half inch copper tubing. On the top of the tubing was an assembly similar to a bubble cap tray to diffuse the entering air stream. On the bottom of the tubing was an adapter to standard one-half inch pipe which lead to the air supply. A piece of one-quarter inch copper tubing was also brazed through the bottom plate. This served as a pressure tap for the manometer. The top of this tubing extended above the top of the air supply tube. There was a one-half inch hole in the plate for drainage of the water from the column.

5. Galvanometer - The galvanometer used was a Leeds and Northrup Company Model 2420-0 reflected beam galvanometer.
6. Gas Measurement Equipment - The gas flow was measured volumetrically with a Precision Scientific Company Wet Test Meter. The meter measures one cubic foot per revolution of the dial and is graduated by units of 0.01 cubic feet. The meter was calibrated with a National Bureau of Standards 0.1 cubic feet standard bottle and was found to be accurate to plus or minus 0.2 per cent.

7. Manometer - The manometer used was a Meriam Instrument Company 20 inch C. O. Standard Cleanout Manometer. The fluid in the manometer was water.
8. Potentiometer - Leeds and Northrup Company Student Potentiometer No. 245486 was used. The coarse adjustments were in one ohm units and the slide wire was one ohm resistance. The fixed resistances were 76 ohms each. The slide wire was calibrated by 0.005 ohms per division.
9. Probe - The probe was manufactured from a piece of rigid styrene plastic tubing with a one-half inch outside diameter. It was two feet long. The bottom of the probe was sealed with a sheet of one-quarter inch plexiglass plastic. Two plastic triangles were glued to the tube even with the bottom. They extended seven-eights inch from the tube and the outside ends were one and one-half inches apart. A one-sixteenth inch hole was drilled through each toward the center of the tube. A coil of No. 29 platinum wire consisting of six loops 1.4 centimeters in diameter was suspended across the tips of the two plastic triangles. Leads were soldered to each end of the coil. These went through the holes in the triangles, up the inside of the tubing, and led to the instrumentation circuit. The distance from the bottom of the probe to the top of the coil was 2.4 centimeters. One the outside of the probe was a strip of millimeter graph paper fastened with aircraft dope. The strip measured from 0

to 32 centimeters from the top of the tubing. The 32 centimeter marking was at the top of the tube. This strip was used to measure the position of the probe. The top of the tube which held the probe served as a reference point. The probe reading was 16.6 centimeters when the bottom of the probe was against the tray in the column.

10. Resistance Box - Leeds and Northrup Company resistance box No. 245486 was used. It supplied resistance from 0 to 9,999 ohms in 1 ohm increments.
11. Thermometer - A Curtin Cumpany mercury thermometer was used. It was graduated from -30° to 120° F. with 1° graduations.
12. Tray - The tray was manufactured from one-sixteenth inch aluminum sheet. It contained 19 one-sixteenth inch holes. The holes were drilled in the pattern shown in Figure 3. Each hole was undercut from the bottom to a diameter of three thirty-seconds inch and to a depth of one thirty-second inch.
13. Voltmeter - A Weston Company Model 280-DC direct current voltmeter was used. Its scale measured from 0 to 3 volts with 0.05 volt gradations.

Procedure

The experimental procedure will be given in consecutive order.

The procedure for taking a measurement of the electrical circuit was as follows: The switch was closed and time was allowed for the hot wire anemometer to reach equilibrium. Then the electrical bridge was balanced by turning the slide wire until the galvanometer reading was zero. The slide wire setting, the amperage, and the resistance box setting were read and recorded.

The preliminary steps were as follows: A slight air flow was started through the column. A measured amount of water was poured in the top of the column onto the tray. The air flow was decreased until no air flowed through the water, The probe was lowered until it was entirely immersed in the water. A measurement of the electrical circuit was made. The probe was raised to the zero position on the probe scale. The air flow was then raised to the desired rate. The rate of air flow was measured with the wet test meter by timing the flow with a stop watch. The temperatures of the wet test meter and of the air inside the column were recorded. The pressure drops across the wet test meter and across the tray were recorded.

The main steps in making an experimental run were: The probe was placed at zero on the probe scale (16.6 centimeters above the tray) and a measurement of the electrical circuit was made. The probe was lowered to the next desired position and again a measurement of the electrical circuit was made. This was continued until the probe was at a position of sixteen centimeters on the probe scale (0.6 centimeters above the tray). Usually the probe was lowered two or three centimeters at a time until a variation in the electrical measurements was found and then it was lowered one centimeter at a time. The probe was then raised and one or two of the electrical readings were checked. The probe was returned to zero position on the probe scale.

The final steps in an experimental run were: The air flow was again determined using the wet test meter. The height of the froth above the tray was measured visually by a reading from the meter stick section inside the column. The air flow was reduced until no air flowed through the water. The liquid level on the tray was read from the meter stick inside the column. The air flow was shut off and the water was drained from the column.

In addition to the data gathered from the experimental runs, the variation of fluid head on the tray with the volume of water present was determined. This was done by pouring measured amounts of water into the column and then reading the liquid level from the meter stick section mounted inside the column. A graph of this data is presented in Figure 13.

Treatment of The Data

The treatment of the data had two primary purposes. The first was to determine if the hot wire anemometer could be used to determine the location of froth levels. The second was to determine if the hot wire anemometer could be used to measure point to point average densities through the froth bed. The treatment of the data is probably best shown by a sample calculation. The following is a sample calculation using run 14.

The calculations to determine if the anemometer could be used to locate froth levels was done as follows: A graph of the slide wire readings as a function of the probe position was made. This curve showed two distinct breaks. One was with the bottom of the probe 6.6 centimeters above the tray. The other was with the bottom of the probe 11.8 centimeters above the tray. The visible foam level was 9.0 centimeters above the tray.

6.6 centimeters - bottom break in graph (Figure 7)

2.4 centimeters - distance from bottom of probe to top of coil

9.0 centimeters

This calculation plus the experimental observation that the lower break in the curve occured at the instant the coil was completely immersed in the foam led to the conclusion that the height of the froth can be accurately indicated by the lower break in the curve.

The calculations made to determine if the hot wire anemometer could be used to determine point to point average densities through the froth bed were as follows: An initial assumption was that the change in slide wire readings times the square of the amperage would be proportional to the square root of the density of the froth bed. This assumption was based upon the previous work of Mr. Davis (See Page 5). The product of the current squared and the change in the slide wire readings from the readings in air and in water were calculated. (Table XXVII)

Probe position - 6.6 centimeters above the tray

Slide wire reading - 0.362 ohms

Change in slide wire reading from reading with the probe in air - 0.498 ohms - 0.362 ohms = 0.136 ohms

Current - 0.351 amperes

$(0.351)^2 \times 0.136 = 0.01673$ watts (From reading with probe in air)

$0.01841 - 0.01673 = 0.00168$ watts (From reading with probe in water)

This data was plotted by use of the assumption of a linear relationship between the wattage figures and the square root of the density. From the graph, the density at each probe position was found. (Table XXVII) Then a graph of density as a function of height above the tray was drawn. (Figure 11) This curve was graphically integrated for the integral of $h(d\rho)$. (h is the height above the tray, $d\rho$ is the differential of density. The limits of integration were a density of 1.000 and a height such that the value of the integral was equal to the weight of water per unit area of tray surface.

Original weight of water - 400 grams

Cross sectional area - 70.0 square centimeters

$\frac{400}{70.0}$ = 5.71 grams per square centimeter of tray

Integration to a value of 5.71 gave a froth height of 9.1 centimeters. The observed froth height and the froth height determined in the first part of the calculations were 9.0 centimeters. Therefore, the assumption was found to be correct.

The following miscellaneous calculations were made:

Flow rate - 8.89 Ft^3/Minute

Cross sectional area - 70.0 square centimeters

Air velocity -

$$\frac{8.89}{70.0} \times 929.034 \frac{Cm^2}{Ft^2} \times \frac{1}{60} \frac{Min}{Sec} = 1.958 \text{ Feet/Second}$$

Initial liquid depth - 5.3 centimeters

Height of froth bed - 9.0 centimeters

Average density -

$$\frac{5.3}{9.0} = 0.588, \quad 0.588 \times 1.000 \frac{Gm.}{CC} = 0.588 \frac{Gm}{CC}$$

A graph of flow rate and average densities was made. (Figure 12) This showed the average density to be approximately a linear function of air velocity for any given fluid head on the tray.

The resistance of the probe was calculated at each probe position. (Table XXVII)

If R_p is the resistance of the probe in ohms

S is the slide wire reading in ohms

Then $$R_p = 2 \frac{(77 - S)}{(76 + S)}$$

Probe position - 6.6 centimeters above the tray

Slide wire reading - 0.362 ohms

$$R_p = 2 \frac{(77 - 0.362)}{(76 + 0.362)} = 2.00723 \text{ ohms}$$

CHAPTER IV

RESULTS

In general, the results of the experimental work showed that the hot wire anemometer can be a useful instrument for locating froth levels and for measuring point to point average densities through a froth bed. The graph of the average density as a function of the velocity of the air stream shows that the relationship between these two properties is linear. The linearity applies for a given fluid head upon the tray. Insufficient data were taken to develop an empirical mathematical relationship between the fluid head on the tray, the velocity of the air stream, and the average density of the froth bed.

Froth Level Location

The results showed that the level of the froth over a tray in equipment of this type can be accurately located with the hot wire anemometer. The sharp break in the graph of the slide wire reading as a function of probe position (Figures 4, 5, 6, and 7) nearest the tray gives the location of the top of the froth accurately. The only requirement is that the break in the curve must be correlated to the top of the hot wire anemometer.

Froth Bed Density Measurements

The fact that the assumption that the square root of the density was linear with the change in slide wire readings times the square of the current can be used to indicate the froth level shows that the assumption was valid. This indicates that the hot wire anemometer can be used to indicate average densities at various points in the froth bed.

The assumption leads to the following mathematical results:

If S_o is the slide wire reading in ohms with the probe in water

S is the slide wire reading in ohms with the probe at any point

R_p is the resistance of the probe in ohms

ρ is the density of the froth bed at any point in grams per cubic centimeter

I is the current in amperes

A is $(77 - S_o)$

B is $(76 + S_o)$

K and C are constants

The assumption states that

$$I^2(S - S_o) = K\sqrt{\rho} + C$$

Since

$$R_p = 2\,\frac{(77 - S)}{(76 + S)}$$

It can be shown that

$$R_p = 2\,\frac{(77 - S_o)\,I^2 - K\sqrt{\rho} - C}{(76 + S_o)\,I^2 + K\sqrt{\rho} + C}$$

or

$$R_p = 2\,\frac{AI^2 - K\sqrt{\rho} - C}{BI^2 + K\sqrt{\rho} + C}$$

from which

$$\rho \approx \left[\frac{2A - B\,R_p}{K(R_p - 2)}\right]^2 I^4$$

R_p varies only about 5 per cent. If it were disregarded in the proportionality, the proportionality could be written as

$$\rho \approx I^4$$

which would give a linear relationship on logarithmic graph paper.

Accuracy

The data in this work were taken to three significant figures. This was sufficient for the accurate location of the froth level. However, to be able to develop an accurate empirical relationship between the hot wire anemometer readings and the average point to point densities in the froth bed, a higher degree of accuracy is needed.

Runs 5 and 6 were defective and were omitted from all calculations. When these two runs were made, two loops of the platinum coil were shorted together.

CHAPTER V

INTERPRETATION OF RESULTS

Summary and Conclusions

The results showed an accurate correlation between the readings obtained from using the hot wire anemometer and the height of the froth bed. The height of the froth bed can be accurately determined from the graphical results. When the anemometer is used for this purpose, the break in the graph of the slide wire reading as a function of probe position must be correlated to the top of the hot wire anemometer.

There was a definite correlation between the readings obtained from the hot wire anemometer and the average point to point densities through the froth bed. Although the data obtained were not of sufficient precision to allow the evaluation of constants, an empirical relationship was established. This relationship was

$$I^2(S - S_o) = K\sqrt{\rho} + C$$

The terms are as defined on page 20.

It was therefore concluded that the hot wire anemometer is an instrument that is useful to locate accurately the froth level over a tray and that it is useful for study of point to point densities through a froth bed. Further, it was concluded that the hot wire anemometer can be used to evaluate the effect of air velocity and fluid head upon froth formation.

Implications of The Study

From the results, it is known, for the first time, that there is an instrument that will allow accurate evaluation of froth formation and behavior. This evaluation will, in turn, permit accurate determination of the behavior of equipment utilizing vapor-liquid mixing which will result in froth formation. More accurate design methods for this type of equipment will also be developed.

Suggestions for Future Study

The construction of more elaborate electrical equipment that will give more precise data is suggested. This will allow full evaluation of the empirical relationship to determine point to point average densities in the froth bed.

It is also suggested that the hot wire anemometer be used with other types of trays and with other liquid-vapor systems. This work will give a basic literature on froth formation and its effects in the equipment and with the systems.

In all future work, it is recommended that some flat array of the hot wire placed horizontal to the tray be used instead of a coiled wire.

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APPENDIX

TABLE I

EXPERIMENTAL DATA FOR RUN 1

Fluid Head - Initial 57.4 - 52.0 Final 57.3 - 52.0 Centimeters

Column Temperature 88 °F Meter Temperature 88 °F

Flow at Start - 10 Cubic Feet in 1 Minute 27.7 Seconds

Tray Manometer, Left -1.0 Right +1.9 Pressure 2.9 Inches Water

Meter Manometer, Left -0.8 Right -1.6 Pressure 0.8 Inches Water

Froth Level by Sight 59.0 - 52.0 Centimeters

Probe Position Centimeters	Amperage	Resistance Ohms	Slide Wire Reading Ohms
In Water	0.363	2.0	0.383
0.0	0.352	2.0	0.537
8.5	0.358	2.0	0.474
9.5	0.359	2.0	0.432
10.5	0.363	2.0	0.394
11.5	0.363	2.0	0.392
12.5	0.364	2.0	0.390
13.5	0.362	2.0	0.388
14.5	0.363	2.0	0.387
15.5	0.363	2.0	0.385
16.5	0.362	2.0	0.384

Flow at End - 10 Cubic Feet in 1 Minute 26.3 Seconds

TABLE II

EXPERIMENTAL DATA FOR RUN 2

Fluid Head - Initial 55.2 - 52.0 Final 55.1 - 52.0 Centimeters

Column Temperature 73 ^{o}F Meter Temperature 86 ^{o}F

Flow at Start - 10 Cubic Feet in 1 Minute 6.6 Seconds

Tray Manometer, Left -0.8 Right +1.7 Pressure 2.5 Inches Water

Meter Manometer, Left -0.5 Right -1.7 Pressure 1.2 Inches Water

Froth Level by Sight 57.5 - 52.0 Centimeters

Probe Position Centimeters	Amperage	Resistance Ohms	Slide Wire Reading Ohms
In Water	0.358	2.0	0.355
0.0	0.351	2.0	0.507
2.0	0.351	2.0	0.513
4.0	0.351	2.0	0.514
7.0	0.353	2.0	0.489
8.0	0.353	2.0	0.475
9.0	0.353	2.0	0.462
10.0	0.355	2.0	0.440
11.0	0.358	2.0	0.412
12.0	0.358	2.0	0.383
13.0	0.360	2.0	0.361
14.0	0.358	2.0	0.358
15.0	0.362	2.0	0.357
16.0	0.358	2.0	0.356
16.5	0.358	2.0	0.355

Flow at End - 10 Cubic Feet in 1 Minute 7.1 Seconds

TABLE III

EXPERIMENTAL DATA FOR RUN 3

Fluid Head - Initial 57.5 - 52.0 Final 57.1 - 52.0 Centimeters

Column Temperature 72 ^{o}F Meter Temperature 86 ^{o}F

Flow at Start - 10 Cubic Feet in 1 Minute 4.4 Seconds

Tray Manometer, Left -1.2 Right +2.1 Pressure 3.3 Inches Water

Meter Manometer, Left -0.4 Right -1.8 Pressure 1.4 Inches Water

Froth Level by Sight 60.0 - 52.0 Centimeters

Probe Position Centimeters	Amperage	Resistance Ohms	Slide Wire Reading Ohms
In Water	0.359	2.0	0.359
0.0	0.351	2.0	0.497
3.0	0.351	2.0	0.496
6.0	0.351	2.0	0.468
7.0	0.355	2.0	0.441
8.0	0.355	2.0	0.410
9.0	0.358	2.0	0.396
10.0	0.359	2.0	0.376
11.0	0.352	2.0	0.367
12.0	0.359	2.0	0.366
13.0	0.359	2.0	0.364
14.0	0.360	2.0	0.363
15.0	0.358	2.0	0.362
16.0	0.359	2.0	0.361
16.5	0.359	2.0	0.359

Flow at End - 9 Cubic Feet in 0 Minute 58.8 Seconds

TABLE IV

EXPERIMENTAL DATA FOR RUN 4

Fluid Head - Initial 59.5 - 52.0 Final 58.5 - 52.0 Centimeters

Column Temperature 78 ^{o}F Meter Temperature 85 ^{o}F

Flow at Start - 10 Cubic Feet in 1 Minute 29.3 Seconds

Tray Manometer, Left -1.3 Right +2.2 Pressure 3.5 Inches Water

Meter Manometer, Left -0.8 Right -1.3 Pressure 0.5 Inches Water

Froth Level by Sight 61.0 - 52.0 Centimeters

Probe Position Centimeters	Amperage	Resistance Ohms	Slide Wire Reading Ohms
In Water	0.352	2.0	0.353
0.0	0.353	2.0	0.476
3.0	0.352	2.0	0.478
5.0	0.352	2.0	0.466
6.0	0.352	2.0	0.448
7.0	0.358	2.0	0.398
8.0	0.359	2.0	0.392
9.0	0.358	2.0	0.367
10.0	0.358	2.0	0.365
11.0	0.358	2.0	0.359
12.0	0.359	2.0	0.362
13.0	0.358	2.0	0.361
14.0	0.355	2.0	0.360
15.0	0.358	2.0	0.358
16.0	0.358	2.0	0.357
16.5	0.352	2.0	0.356

Flow at End - 10 Cubic Feet in 1 Minute 26.9 Seconds

TABLE V

EXPERIMENTAL DATA FOR RUN 7

Fluid Head Initial 60.5 - 52.0 Final 59.3 - 52.0 Centimeters

Column Temperature 84 °F Meter Temperature 86 °F

Flow at Start - 10 Cubic Feet in 1 Minute 8.4 Seconds

Tray Manometer, Left -1.5 Right +2.4 Pressure 3.9 Inches Water

Meter Manometer, Left 0.7 Right -0.5 Pressure 1.2 Inches Water

Froth Level by Sight 62.5 - 52.0 Centimeters

Probe Position Centimeters	Amperage	Resistance Ohms	Slide Wire Reading Ohms
In Water	0.358	2.0	0.357
0.0	0.348	2.0	0.504
1.0	0.349	2.0	0.496
2.0	0.350	2.0	0.477
3.0	0.350	2.0	0.474
4.0	0.351	2.0	0.456
5.0	0.353	2.0	0.418
6.0	0.353	2.0	0.398
7.0	0.355	2.0	0.382
8.0	0.357	2.0	0.371
9.0			
9.0	0.357	2.0	0.367
10.0	0.358	2.0	0.366
11.0	0.355	2.0	0.364
12.0	0.357	2.0	0.363
13.0	0.358	2.0	0.362
14.0	0.356	2.0	0.361
15.0	0.357	2.0	0.359
16.0	0.357	2.0	0.357

Flow at End - 10 Cubic Feet in 1 Minute 10.9 Seconds

TABLE VI

EXPERIMENTAL DATA FOR RUN 8

Fluid Head - Initial 54.5 - 52.0 Final 54.0 - 52.0 Centimeters

Column Temperature 73 ^{o}F Meter Temperature 85 ^{o}F

Flow at Start - 10 Cubic Feet in 1 Minute 18.4 Seconds

Tray Manometer, Left -0.5 Right +1.3 Pressure 1.8 Inches Water

Meter Manometer, Left +0.5 Right -0.3 Pressure 0.8 Inches Water

Froth Level by Sight 56.0 - 52.0 Centimeters

Probe Position Centimeters	Amperage	Resistance Ohms	Slide Wire Reading Ohms
In Water	0.348	2.0	0.352
0.0	0.347	2.0	0.506
2.0	0.348	2.0	0.509
4.0	0.345	2.0	0.505
6.0	0.345	2.0	0.502
7.0	0.349	2.0	0.493
8.0	0.347	2.0	0.490
10.0	0.348	2.0	0.469
11.0	0.348	2.0	0.458
12.0	0.349	2.0	0.417
13.0	0.351	2.0	0.384
14.0	0.352	2.0	0.358
15.0	0.353	2.0	0.354
16.0	0.352	2.0	0.352

Flow at End - 10 Cubic Feet in 1 Minutes 18.0 Seconds

TABLE VII

EXPERIMENTAL DATA FOR RUN 9

Fluid Head - Initial 54.5 - 52.0 Final 54.5 - 52.0 Centimeters

Column Temperature 79 ^{o}F Meter Temperature 82 ^{o}F

Flow at Start - 5 Cubic Feet in 1 Minute 56.5 Seconds

Tray Manometer, Left -0.2 Right +1.0 Pressure 1.2 Inches Water

Meter Manometer, Left -- Right -- Pressure Neg. Inches Water

Froth Level by Sight 55.0 - 52.0 Centimeters

Probe Position Centimeters	Amperage	Resistance Ohms	Slide Wire Reading Ohms
In Water	0.353	2.0	0.373
0.0	0.348	2.0	0.510
3.0	0.347	2.0	0.520
6.0	0.348	2.0	0.522
9.0	0.349	2.0	0.523
11.0	0.346	2.0	0.524
12.0	0.345	2.0	0.518
13.0	0.347	2.0	0.507
14.0	0.351	2.0	0.428
15.0	0.352	2.0	0.377
16.0	0.355	2.0	0.373

Flow at End - 5 Cubic Feet in 1 Minute 59.5 Seconds

TABLE VIII

EXPERIMENTAL DATA FOR RUN 10

Fluid Head - Initial 55.5 - 52.0 Final 55.4 - 52.0 Centimeters

Column Temperature 76 °F Meter Temperature 82 °F

Flow at Start - 5 Cubic Feet in 1 Minute 6.4 Seconds

Tray Manometer, Left -0.6 Right +1.3 Pressure 1.9 Inches Water

Meter Manometer, Left +0.2 Right 0.0 Pressure 0.2 Inches Water

Froth Level by Sight 56.5 - 52.0 Centimeters

Probe Position Centimeters	Amperage	Resistance Ohms	Slide Wire Reading Ohms
In Water	0.352	2.0	0.362
0.0	0.342	2.0	0.507
3.0	0.344	2.0	0.507
6.0	0.346	2.0	0.508
8.0	0.343	2.0	0.494
9.0	0.344	2.0	0.487
10.0	0.345	2.0	0.489
11.0	0.346	2.0	0.475
12.0	0.348	2.0	0.419
13.0	0.351	2.0	0.378
14.0	0.351	2.0	0.364
15.0	0.352	2.0	0.363
16.0	0.352	2.0	0.362

Flow at End - 5 Cubic Feet in 1 Minute 9.2 Seconds

TABLE IX

EXPERIMENTAL DATA FOR RUN 11

Fluid Head - Initial 57.5 - 52.0 Final 57.4 - 52.0 Centimeters

Column Temperature 80 °F Meter Temperature 84 °F

Flow at Start - 5 Cubic Feet in 1 Minute 13.8 Seconds

Tray Manometer, Left -0.9 Right +1.7 Pressure 2.6 Inches Water

Meter Manometer, Left +0.2 Right 0.0 Pressure 0.2 Inches Water

Froth Level by Sight 58.5 - 52.0 Centimeters

Probe Position Centimeters	Amperage	Resistance Ohms	Slide Wire Reading Ohms
In Water	0.350	2.0	0.384
0.0	0.345	2.0	0.509
3.0	0.344	2.0	0.511
6.0	0.345	2.0	0.511
7.0	0.345	2.0	0.510
8.0	0.343	2.0	0.507
9.0	0.342	2.0	0.494
10.0	0.345	2.0	0.449
11.0	0.350	2.0	0.406
12.0	0.351	2.0	0.388
13.0	0.352	2.0	0.387
14.0	0.352	2.0	0.386
15.0	0.351	2.0	0.385
16.0	0.350	2.0	0.385

Flow at End - 5 Cubic Feet in 1 Minute 19.8 Seconds

TABLE X

EXPERIMENTAL DATA FOR RUN 12

Fluid Head - Initial 54.5 - 52.0 Final 53.9 - 52.0 Centimeters

Column Temperature 73 ^{o}F Meter Temperature 85 ^{o}F

Flow at Start - 10 Cubic Feet in 1 Minute 6.1 Seconds

Tray Manometer, Left -0.9 Right +1.7 Pressure 2.6 Inches Water

Meter Manometer, Left +1.0 Right -0.8 Pressure 1.8 Inches Water

Froth Level by Sight 57.0 - 52.0 Centimeters

Probe Position Centimeters	Amperage	Resistance Ohms	Slide Wire Reading Ohms
In Water	0.351	2.0	0.349
0.0	0.346	2.0	0.489
3.0	0.347	2.0	0.488
6.0	0.345	2.0	0.484
8.0	0.345	2.0	0.472
9.0	0.346	2.0	0.451
10.0	0.348	2.0	0.435
11.0	0.349	2.0	0.408
12.0	0.350	2.0	0.384
13.0	0.351	2.0	0.366
14.0	0.351	2.0	0.352
15.0	0.351	2.0	0.351
16.0	0.351	2.0	0.349

Flow at End - 10 Cubic Feet in 1 Minute 6.8 Seconds

TABLE XI

EXPERIMENTAL DATA FOR RUN 13

Fluid Head - Initial 55.5 - 52.0 Final 55.4 - 52.0 Centimeters

Column Temperature 67 ^{o}F Meter Temperature 80 ^{o}F

Flow at Start - 10 Cubic Feet in 1 Minute 7.2 Seconds

Tray Manometer, Left -1.1 Right +1.9 Pressure 3.0 Inches Water

Meter Manometer, Left +1.0 Right -0.8 Pressure 1.8 Inches Water

Froth Level by Sight 58.0 - 52.0 Centimeters

Probe Position Centimeters	Amperage	Resistance Ohms	Slide Wire Reading Ohms
In Water	0.355	2.0	0.328
0.0	0.347	2.0	0.472
3.0	0.348	2.0	0.462
6.0	0.347	2.0	0.453
8.0	0.349	2.0	0.434
9.0	0.350	2.0	0.419
10.0	0.351	2.0	0.382
11.0	0.352	2.0	0.359
12.0	0.353	2.0	0.336
13.0	0.355	2.0	0.329
14.0	0.354	2.0	0.328
15.0	0.354	2.0	0.326
16.0	0.355	2.0	0.325

Flow at End - 10 Cubic Feet in 1 Minute 6.2 Seconds

TABLE XII

EXPERIMENTAL DATA FOR RUN 14

Fluid Head - Initial 57.5 - 52.0 Final 57.0 - 52.0 Centimeters

Column Temperature 72 ^{o}F Meter Temperature 81 ^{o}F

Flow at Start - 10 Cubic Feet in 1 Minute 6.0 Seconds

Tray Manometer, Left -1.3 Right +2.1 Pressure 3.4 Inches Water

Meter Manometer, Left +0.9 Right -0.7 Pressure 1.6 Inches Water

Froth Level by Sight 60.0 - 52.0 Centimeters

Probe Position Centimeters	Amperage	Resistance Ohms	Slide Wire Reading Ohms
In Water	0.351	2.0	0.351
0.0	0.344	2.0	0.498
2.0	0.345	2.0	0.491
4.0	0.345	2.0	0.480
5.0	0.346	2.0	0.468
6.0	0.347	2.0	0.459
7.0	0.347	2.0	0.449
8.0	0.349	2.0	0.404
9.0	0.350	2.0	0.378
10.0	0.351	2.0	0.362
11.0	0.351	2.0	0.354
12.0	0.350	2.0	0.353
13.0	0.351	2.0	0.351
14.0	0.352	2.0	0.350
15.0	0.351	2.0	0.350
16.0	0.352	2.0	0.350

Flow at End - 10 Cubic Feet in 1 Minute 8.9 Seconds

TABLE XIII

EXPERIMENTAL DATA FOR RUN 15

Fluid Head - Initial 59.5 - 52.0 Final 58.5 - 52.0 Centimeters

Column Temperature 73 °F Meter Temperature 82 °F

Flow at Start - 10 Cubic Feet in 1 Minute 7.2 Seconds

Tray Manometer, Left +1.6 Right -2.4 Pressure 4.0 Inches Water

Meter Manometer, Left +0.9 Right -0.7 Pressure 1.6 Inches Water

Froth Level by Sight 62.0 - 52.0 Centimeters

Probe Position Centimeters	Amperage	Resistance Ohms	Slide Wire Reading Ohms
In Water	0.350	2.0	0.353
0.0	0.342	2.0	0.475
2.0	0.342	2.0	0.468
4.0	0.344	2.0	0.453
5.0	0.345	2.0	0.431
6.0	0.348	2.0	0.397
7.0	0.349	2.0	0.378
8.0	0.349	2.0	0.364
9.0	0.350	2.0	0.359
10.0	0.350	2.0	0.357
11.0	0.350	2.0	0.356
12.0	0.350	2.0	0.355
13.0	0.350	2.0	0.354
14.0	0.350	2.0	0.353
15.0	0.350	2.0	0.352
16.0	0.350	2.0	0.352

Flow at End - 10 Cubic Feet in 1 Minute 8.0 Seconds

TABLE XIV

EXPERIMENTAL DATA FOR RUN 16

Fluid Head - Initial 60.5 - 52.0 Final 59.8 - 52.0 Centimeters

Column Temperature 73 °F Meter Temperature 83 °F

Flow at Start - 10 Cubic Feet in 1 Minute 7.6 Seconds

Tray Manometer, Left -0.2 Right +1.1 Pressure 1.3 Inches Water

Meter Manometer, Left +1.0 Right -0.8 Pressure 1.8 Inches Water

Froth Level by Sight 64.0 - 52.0 Centimeters

Probe Position Centimeters	Amperage	Resistance Ohms	Slide Wire Reading Ohms
In Water	0.350	2.0	0.359
0.0	0.344	2.0	0.462
2.0	0.344	2.0	0.463
3.0	0.345	2.0	0.453
4.0	0.345	2.0	0.417
5.0	0.348	2.0	0.398
6.0	0.351	2.0	0.380
7.0	0.350	2.0	0.371
8.0	0.350	2.0	0.369
9.0	0.351	2.0	0.367
10.0	0.350	2.0	0.365
11.0	0.350	2.0	0.363
12.0	0.350	2.0	0.361
13.0	0.350	2.0	0.360
14.0	0.350	2.0	0.359
15.0	0.350	2.0	0.358
16.0	0.350	2.0	0.356

Flow at End - 10 Cubic Feet in 1 Minute 7.9 Seconds

TABLE XV

GENERAL TABLE OF CALCULATIONS

Run	Original Depth Cm.'	Final Depth Cm.'	Average Depth Cm.'	Rate of Flow Ft^3/Min	Velocity of Air Ft/Sec	Froth Level by Sight Cm'
1	5.5	5.3	5.4	6.90	1.528	8.0
2	3.5	3.3	3.4	8.51	1.885	6.5
3	5.5	5.1	5.3	9.80	2.170	9.5
4	7.5	6.5	7.0	6.60	1.460	10.0
7	8.5	7.3	7.9	8.67	1.1918	11.5
8	2.5	2.0	2.3	7.68	1.698	5.0
9	2.5	2.4	2.5	8.67	1.122	4.0
10	3.5	3.3	3.4	8.85	1.958	5.6
11	5.5	5.3	5.4	7.87	1.742	7.6
12	2.5	1.9	2.2	8.98	1.988	6.0
13	3.5	3.3	3.4	9.03	2.000	7.0
14	5.5	5.3	5.4	8.89	1.968	9.0
15	7.5	6.5	7.0	8.85	1.958	11.0
16	8.5	7.8	8.1	8.86	1.961	13.0

' All depths are given in centimeters above the tray.

TABLE XV (CONTINUED)

Run	Lower Break in Graph" Cm.'	Lower Break in Graph Corrected to Top of Coil Cm.'	Froth Level by Sight Minus Previous Column Cm.'	Average Density Gm/C.C.
1	6.1	8.5	-0.5	0.675
2	3.8	6.3	+0.2	0.508
3	6.5	8.9	+0.6	0.548
4	7.6	10.0	0.0	0.700
7	8.8	11.2	+0.3	0.687
8	2.6	5.0	0.0	0.460
9	1.6	4.0	0.0	0.650
10	3.4	5.8	-0.2	0.607
11	5.2	7.6	0.0	0.711
12	3.0	5.4	+0.6	0.367
13	4.4	6.8	+0.2	0.487
14	6.6	9.0	0.0	0.588
15	8.6	11.0	0.0	0.637
16	10.5	12.9	+0.1	0.623

" Graph is the graph of slide wire readings as a function of probe position. - Figures 4, 5, 6, and 7.

TABLE XV (CONTINUED)

Run	Froth Height From $\int h(d\rho)$ on Graph''' Cm.'	Measured Froth Height Minus Froth Height From Integral Cm.'	Observed Froth Height Minus Froth Height From Integral Cm.'
1	8.3	+0.2	-0.3
2	6.4	-0.1	+0.1
3	9.3	-0.4	+0.2
4	10.2	-0.2	-0.2
7	11.7	-0.5	-0.2
8	4.8	+0.2	+0.2
9	4.0	0.0	0.0
10	5.6	+0.2	0.0
11	7.6	0.0	0.0
12	5.8	-0.4	+0.2
13	6.8	0.0	+0.2
14	9.1	-0.1	-0.1
15	11.2	-0.2	-0.2
16	13.4	+0.5	+0.4

''' Graph is the graph of density as a function of height above the tray. - Figures 8, 9, 10, and 11.

TABLE XVI

CALCULATIONS FOR RUN 1

Probe Position	Height Above Tray	$I^2 \Delta R$ From Water	Density	Resistance of Probe
Cm.	Cm.	Watts	Gm/C.C.	Ohms
0.0	16.6	0.02072	0.0013	1.99806
8.5	8.1	0.01219	0.164	2.00134
9.5	7.1	0.00673	0.462	2.00354
10.5	6.1	0.00142	0.857	2.00554
11.5	5.1	0.00117	0.880	2.00564
12.5	4.1	0.00079	0.906	2.00574
13.5	3.1	0.00075	0.932	2.00586
14.5	2.1	0.00049	0.945	2.00590
15.5	1.1	0.00027	0.969	2.00602
16.5	0.1	0.00022	0.984	2.00606
In Water	---	0.00000	1.000	2.00612

TABLE XVII

CALCULATIONS FOR RUN 2

Probe Position	Height Above Tray	$I^2 \Delta R$ From Water	Density	Resistance of Probe
Cm.	Cm.	Watts	Gm/C.C.	Ohms
0.0	16.6	0.02025	0.0013	1.99963
2.0	14.6	0.02025	0.0013	1.99937
4.0	12.6	0.02025	0.0013	1.99927
7.0	9.6	0.01751	0.024	2.00057
9.0	7.6	0.01413	0.103	2.00199
10.0	6.6	0.01257	0.209	2.00314
11.0	5.6	0.00955	0.399	2.00461
12.0	4.6	0.00383	0.659	2.00613
13.0	3.6	0.00077	0.898	2.00728
14.0	2.6	0.00063	0.933	2.00744
15.0	1.6	0.00005	0.946	2.00749
16.0	0.6	0.00035	0.961	2.00754
16.5	0.1	0.00020	0.972	2.00760
In Water	---	0.00000	1.000	2.00770

TABLE XVIII

CALCULATIONS FOR RUN 3

Probe Position	Height Above Tray	$I^2 \Delta R$ From Water	Density	Resistance of Probe
Cm.	Cm.	Watts	Gm/C.C.	Ohms
0.0	16.6	0.01792	0.0013	2.00016
3.0	13.6	0.01780	0.0013	2.00021
6.0	10.6	0.01434	0.048	2.00167
7.0	9.6	0.01086	0.169	2.00309
8.0	8.6	0.00694	0.404	2.00471
9.0	7.6	0.00496	0.544	2.00544
10.0	6.6	0.00232	0.779	2.00649
11.0	5.6	0.00180	0.900	2.00697
12.0	4.6	0.00102	0.914	2.00702
13.0	3.6	0.00076	0.935	2.00707
14.0	2.6	0.00052	0.956	2.00718
15.0	1.6	0.00050	0.970	2.00723
16.0	0.6	0.00040	0.986	2.00728
16.5	0.1	0.00012	0.998	2.00739
In Water	---	0.00000	1.000	2.00733

TABLE XIX

CALCULATIONS FOR RUN 4

Probe Position	Height Above Tray	$I^2 \Delta R$ From Water	Density	Resistance of Probe
Cm.	Cm.	Watts	Gm/C.C.	Ohms
0.0	16.6	0.01538	0.0013	2.00125
3.0	13.6	0.01538	0.0013	2.00115
5.0	11.6	0.01401	0.008	2.00178
6.0	10.6	0.01178	0.054	2.00272
7.0	9.6	0.00526	0.407	2.00534
8.0	8.6	0.00441	0.472	2.00565
9.0	7.6	0.00130	0.788	2.00697
10.0	6.6	0.00105	0.817	2.00707
11.0	5.6	0.00028	0.907	2.00739
12.0	4.6	0.00056	0.861	2.00723
13.0	3.6	0.00050	0.876	2.00728
14.0	2.6	0.00063	0.892	2.00733
15.0	1.6	0.00016	0.926	2.00744
16.0	0.6	0.00000	0.941	2.00749
16.5	0.1	0.00038	0.954	2.00754
In Water	---	0.00000	1.000	2.00770

TABLE XX

CALCULATIONS FOR RUN 7

Probe Position	Height Above Tray	$I^2 \Delta R$ From Water	Density	Resistance of Probe
Cm.	Cm.	Watts	Gm/C.C.	Ohms
0.0	16.6	0.01888	0.0013	1.99979
1.0	15.6	0.01790	0.003	2.00021
2.0	14.6	0.01557	0.033	2.00120
3.0	13.6	0.01521	0.042	2.00136
4.0	12.6	0.01296	0.106	2.00230
5.0	11.6	0.00817	0.342	2.00429
6.0	10.6	0.00566	0.520	2.00534
7.0	9.6	0.00350	0.691	2.00618
8.0	8.6	0.00196	0.819	2.00676
9.0	7.6	0.00146	0.868	2.00694
10.0	6.6	0.00118	0.884	2.00702
11.0	5.6	0.00123	0.906	2.00712
12.0	4.6	0.00096	0.921	2.00718
13.0	3.6	0.00067	0.935	2.00723
14.0	2.6	0.00068	0.946	2.00728
15.0	1.6	0.00043	0.974	2.00739
16.0	0.6	0.00018	0.990	2.00749
In Water	---	0.00000	1.000	2.00749

TABLE XXI

CALCULATIONS FOR RUN 8

Probe Position	Height Above Tray	$I^2 \Delta R$ From Water	Density	Resistance of Probe
Cm.	Cm.	Watts	Gm/C.C.	Ohms
0.0	16.6	0.01910	0.0013	1.99864
2.0	14.6	0.01910	0.0013	1.99953
4.0	12.6	0.01898	0.0013	1.99974
6.0	10.6	0.01862	0.0013	1.99989
7.0	9.6	0.01873	0.007	2.00037
8.0	8.6	0.01718	0.010	2.00052
9.0	7.6	0.01462	0.030	2.00162
10.0	6.6	0.01462	0.057	2.00220
11.0	5.6	0.01329	0.095	2.00434
12.0	4.6	0.00828	0.333	2.00607
13.0	3.6	0.00408	0.622	2.00744
14.0	2.6	0.00077	0.824	2.00765
15.0	1.6	0.00018	0.968	2.00775
16.0	0.6	0.00000	0.984	2.00775
In Water	---	0.00000	1.000	2.00775

TABLE XXII

CALCULATIONS FOR RUN 9

Probe Position Cm.	Height Above Tray Cm.	$I^2 \Delta R$ From Water Watts	Density Gm/C.C.	Resistance of Probe Ohms
0.0	16.6	0.01928	0.0013	1.99948
3.0	13.6	0.01928	0.0013	1.99895
6.0	10.6	0.01928	0.0013	1.99885
9.0	7.6	0.01928	0.0013	1.99880
11.0	5.6	0.01928	0.0013	1.99874
12.0	4.6	0.01857	0.0017	1.99906
13.0	3.6	0.01724	0.012	1.99963
14.0	2.6	0.00746	0.398	2.00377
15.0	1.6	0.00106	0.931	2.00644
16.0	0.6	0.00016	0.990	2.00665
In Water	---	0.00000	1.000	2.00676

TABLE XXIII

CALCULATIONS FOR RUN 10

Probe Position Cm.	Height Above Tray Cm.	$I^2 \Delta R$ From Water Watts	Density Gm/C.C.	Resistance of Probe Ohms
0.0	16.6	0.01795	0.0013	1.99963
3.0	13.6	0.01795	0.0013	1.99963
6.0	10.6	0.01795	0.0013	1.99958
8.0	8.6	0.01642	0.009	2.00031
9.0	7.6	0.01558	0.020	2.00068
10.0	6.6	0.01580	0.017	2.00057
11.0	5.6	0.01412	0.051	2.00131
12.0	4.6	0.00733	0.368	2.00424
13.0	3.6	0.00206	0.786	2.00639
14.0	2.6	0.00034	0.964	2.00712
15.0	1.6	0.00010	0.978	2.00718
16.0	0.6	0.00005	0.990	2.00723
In Water	---	0.00000	1.000	2.00723

TABLE XXIV

CALCULATIONS FOR RUN 11

Probe Position	Height Above Tray	$I^2 \Delta R$ From Water	Density	Resistance of Probe
Cm.	Cm.	Watts	Gm/C.C.	Ohms
0.0	16.6	0.01562	0.0013	1.99953
3.0	13.6	0.01562	0.0013	1.99942
6.0	10.6	0.01562	0.0013	1.99942
7.0	9.6	0.01550	0.0013	1.99948
8.0	8.6	0.01515	0.0015	1.99963
9.0	7.6	0.01363	0.018	2.00031
10.0	6.6	0.00824	0.241	2.00267
11.0	5.6	0.00275	0.682	2.00492
12.0	4.6	0.00049	0.937	2.00586
13.0	3.6	0.00027	0.952	2.00592
14.0	2.6	0.00022	0.966	2.00597
15.0	1.6	0.00017	0.976	2.00602
16.0	0.6	0.00011	0.984	2.00602
In Water	---	0.00000	1.000	2.00607

TABLE XXV

CALCULATIONS FOR RUN 12

Probe Position	Height Above Tray	$I^2 \Delta R$ From Water	Density	Resistance of Probe
Cm.	Cm.	Watts	Gm/C.C.	Ohms
0.0	16.6	0.01736	0.0013	2.00057
3.0	13.6	0.01724	0.0015	2.00063
6.0	10.6	0.01677	0.004	2.00084
8.0	8.6	0.01534	0.015	2.00146
9.0	7.6	0.01281	0.072	2.00256
10.0	6.6	0.01083	0.146	2.00340
11.0	5.6	0.00714	0.329	2.00482
12.0	4.6	0.00450	0.554	2.00607
13.0	3.6	0.00221	0.762	2.00702
14.0	2.6	0.00049	0.942	2.00775
15.0	1.6	0.00036	0.956	2.00781
16.0	0.6	0.00013	0.984	2.00791
In Water	---	0.00000	1.000	2.00796

TABLE XXVI

CALCULATIONS FOR RUN 13

Probe Position	Height Above Tray	$I^2 \Delta R$ From Water	Density	Resistance of Probe
Cm.	Cm.	Watts	Gm/C.C.	Ohms
0.0	16.6	0.01852	0.0013	2.00146
3.0	13.6	0.01731	0.005	2.00199
6.0	10.6	0.01624	0.017	2.00246
8.0	8.6	0.01511	0.066	2.00345
9.0	7.6	0.01204	0.128	2.00424
10.0	6.6	0.00744	0.374	2.00618
11.0	5.6	0.00450	0.590	2.00739
12.0	4.6	0.00154	0.854	2.00859
13.0	3.6	0.00052	0.947	2.00896
14.0	2.6	0.00050	0.954	2.00901
15.0	1.6	0.00030	0.984	2.00912
16.0	0.6	0.00005	0.995	2.00917
In Water	---	0.00000	1.000	2.00917

TABLE XXVII

CALCULATIONS FOR RUN 14

Probe Position	Height Above Tray	$I^2 \Delta R$ From Water	Density	Resistance of Probe
Cm.	Cm.	Watts	Gm/C.C.	Ohms
0.0	16.6	0.01841	0.0013	2.00010
2.0	14.6	0.01758	0.002	2.00047
4.0	12.6	0.01627	0.014	2.00105
5.0	11.6	0.01482	0.040	2.00167
6.0	10.6	0.01372	0.067	2.00214
7.0	9.6	-------	-----	2.00312
8.0	8.6	0.00596	0.394	2.00502
9.0	7.6	0.00573	0.646	2.00639
10.0	6.6	0.00168	0.826	2.00723
11.0	5.6	0.00093	0.929	2.00765
12.0	4.6	0.00069	0.942	2.00770
13.0	3.6	0.00031	0.968	2.00781
14.0	2.6	0.00011	0.974	2.00786
15.0	1.6	0.00011	0.980	2.00786
16.0	0.6	0.00000	1.000	2.00786
In Water	---	0.00000	1.000	2.00781

TABLE XXVIII

CALCULATIONS FOR RUN 15

Probe Position	Height Above Tray	$I^2 \Delta R$ From Water	Density	Resistance of Probe
Cm.	Cm.	Watts	Gm/C.C.	Ohms
0.0	16.6	0.01505	0.0013	2.00131
2.0	14.6	0.01423	0.003	2.00167
4.0	12.6	0.01245	0.031	2.00246
5.0	11.6	0.00982	0.124	2.00361
6.0	10.6	0.00561	0.394	2.00539
7.0	9.6	0.00323	0.643	2.00639
8.0	8.6	0.00153	0.803	2.00712
9.0	7.6	0.00085	0.877	2.00739
10.0	6.6	0.00060	0.908	2.00746
11.0	5.6	0.00050	0.924	2.00754
12.0	4.6	0.00036	0.941	2.00760
13.0	3.6	0.00020	0.950	2.00765
14.0	2.6	0.00017	0.964	2.00770
15.0	1.6	0.00005	0.980	2.00775
16.0	0.6	0.00000	0.990	2.00770
In Water	---	0.00000	1.000	2.00770

TABLE XXIX

CALCULATIONS FOR RUN 16

Probe Position	Height Above Tray	$I^2 \Delta R$ From Water	Density	Resistance of Probe
Cm.	Cm.	Watts	Gm/C. C.	Ohms
0.0	16.6	0.01310	0.0013	2.00199
2.0	14.6	0.01310	0.0013	2.00193
3.0	13.6	0.01191	0.085	2.00246
4.0	12.6	0.00763	0.179	2.00434
5.0	11.6	0.00623	0.358	2.00534
6.0	10.6	0.00289	0.587	2.00628
7.0	9.6	0.00186	0.721	2.00676
8.0	8.6	0.00160	0.752	2.00686
9.0	7.6	0.00128	0.785	2.00697
10.0	6.6	0.00102	0.818	2.00707
11.0	5.6	0.00087	0.846	2.00718
12.0	4.6	0.00062	0.884	2.00728
13.0	3.6	0.00050	0.896	2.00733
14.0	2.6	0.00038	0.915	2.00739
15.0	1.6	0.00027	0.942	2.00744
16.0	0.6	0.00000	0.978	2.00754
In Water	---	0.00000	1.000	2.00754

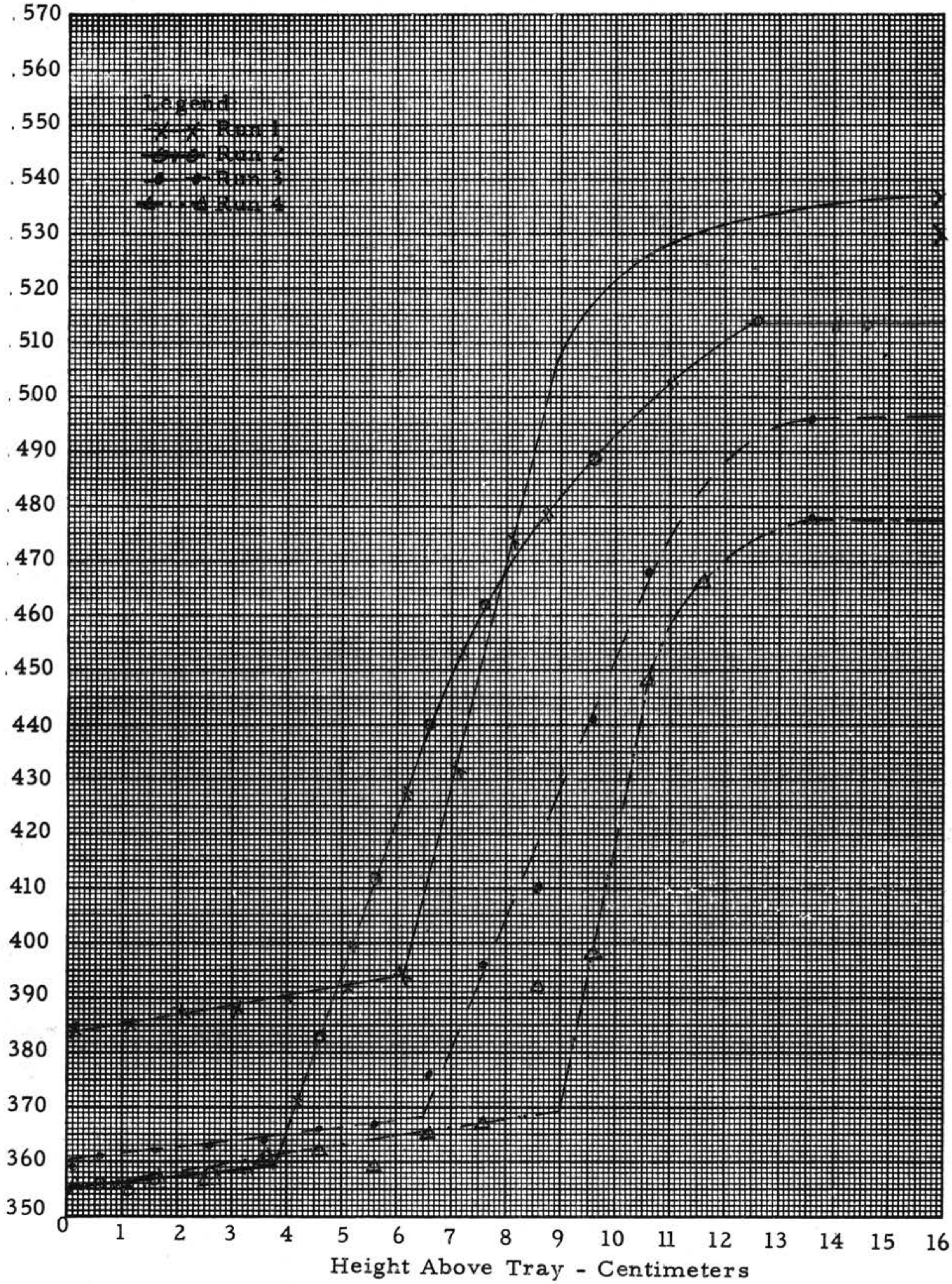

FIGURE 4

Slide Wire Readings As A Function of Probe Position
Runs 1, 2, 3, and 4

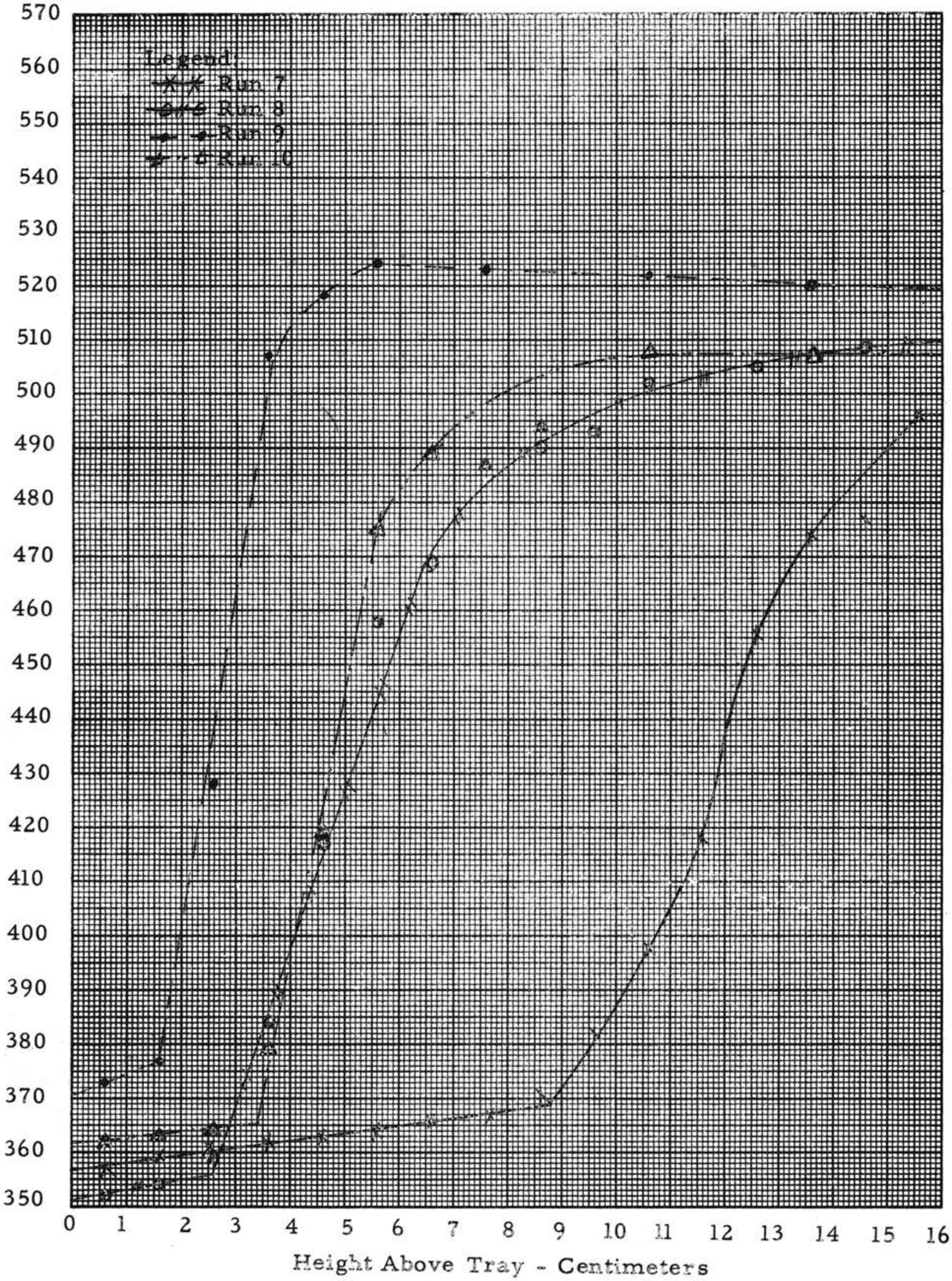

FIGURE 5

Slide Wire Readings As A Function of Probe Height
Runs 7, 8, 9, and 10

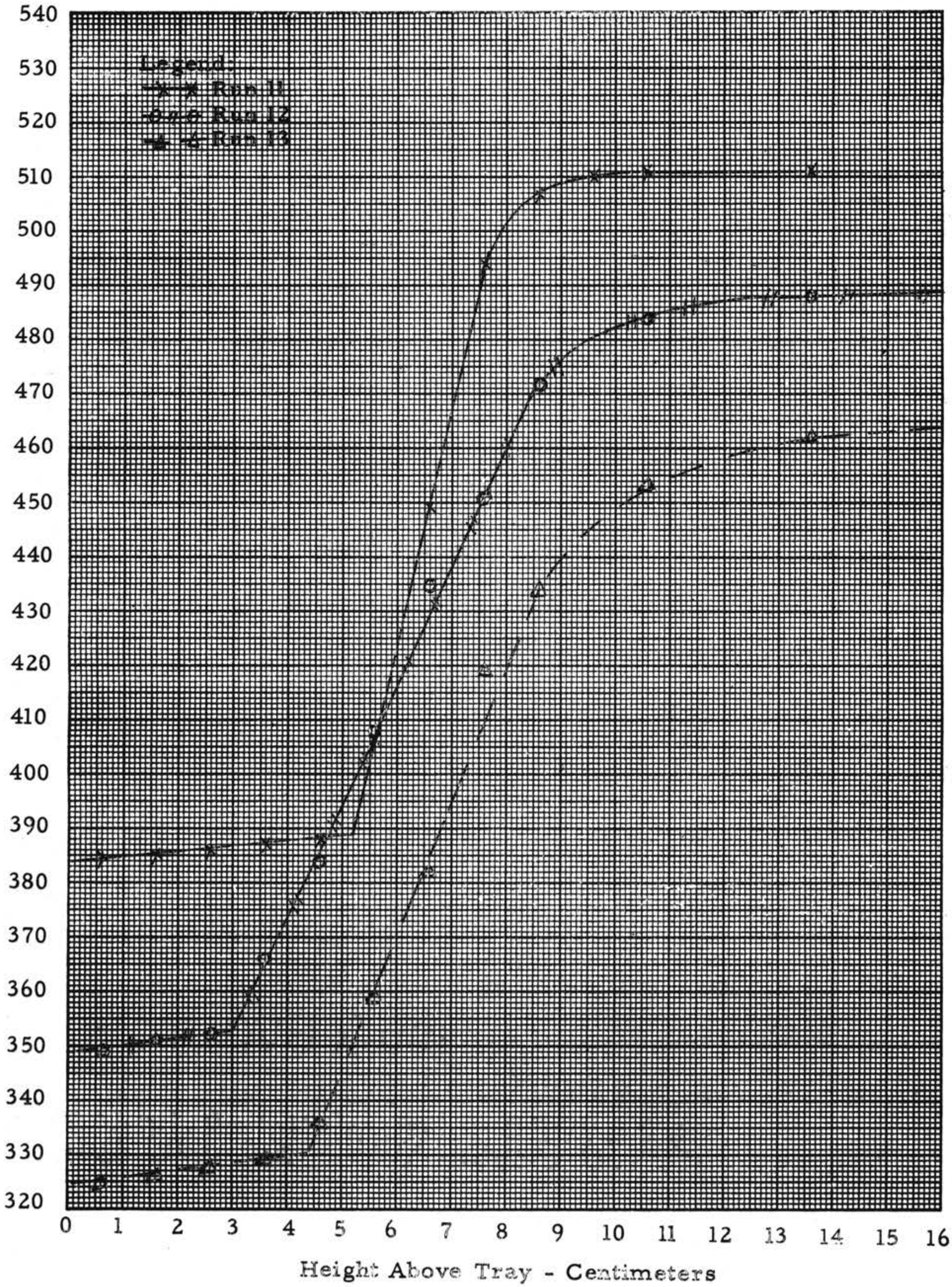

FIGURE 6

Slide Wire Readings As A Function of Probe Height
Runs 11, 12, and 13

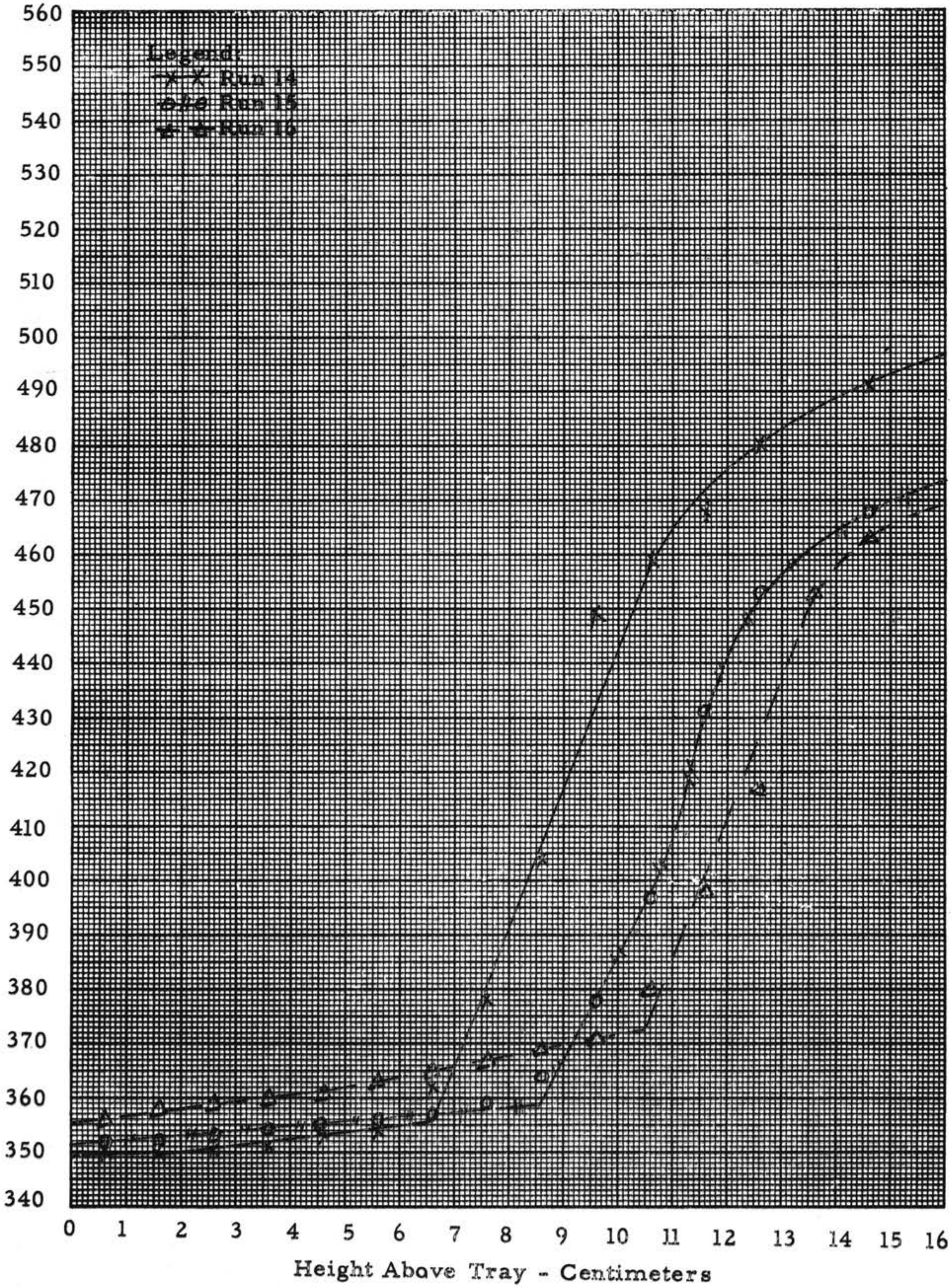

Figure 7

Slide Wire Readings As A Function of Probe Height

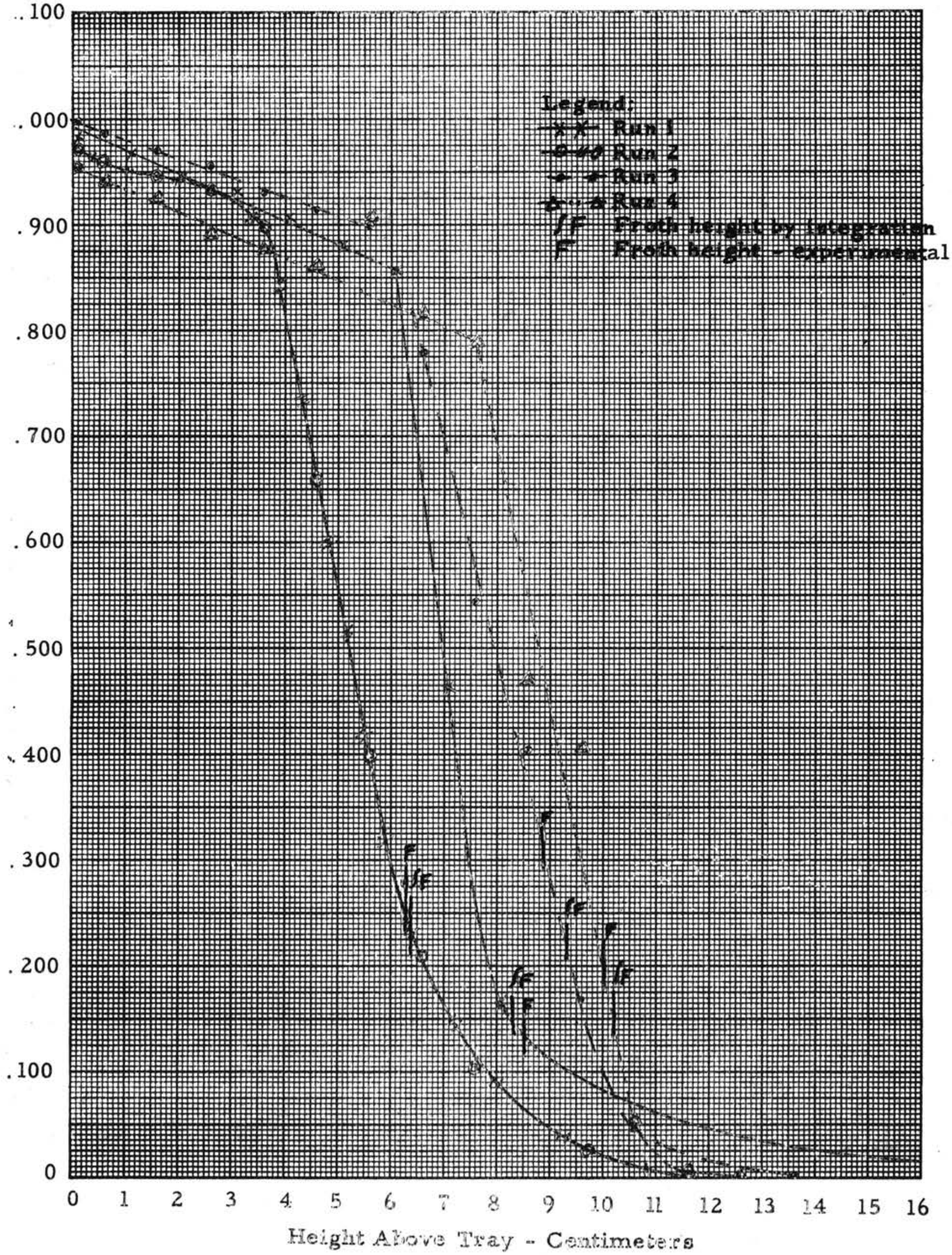

FIGURE 8

Density As A Function of Height Above Tray
Runs 1, 2, 3, and 4

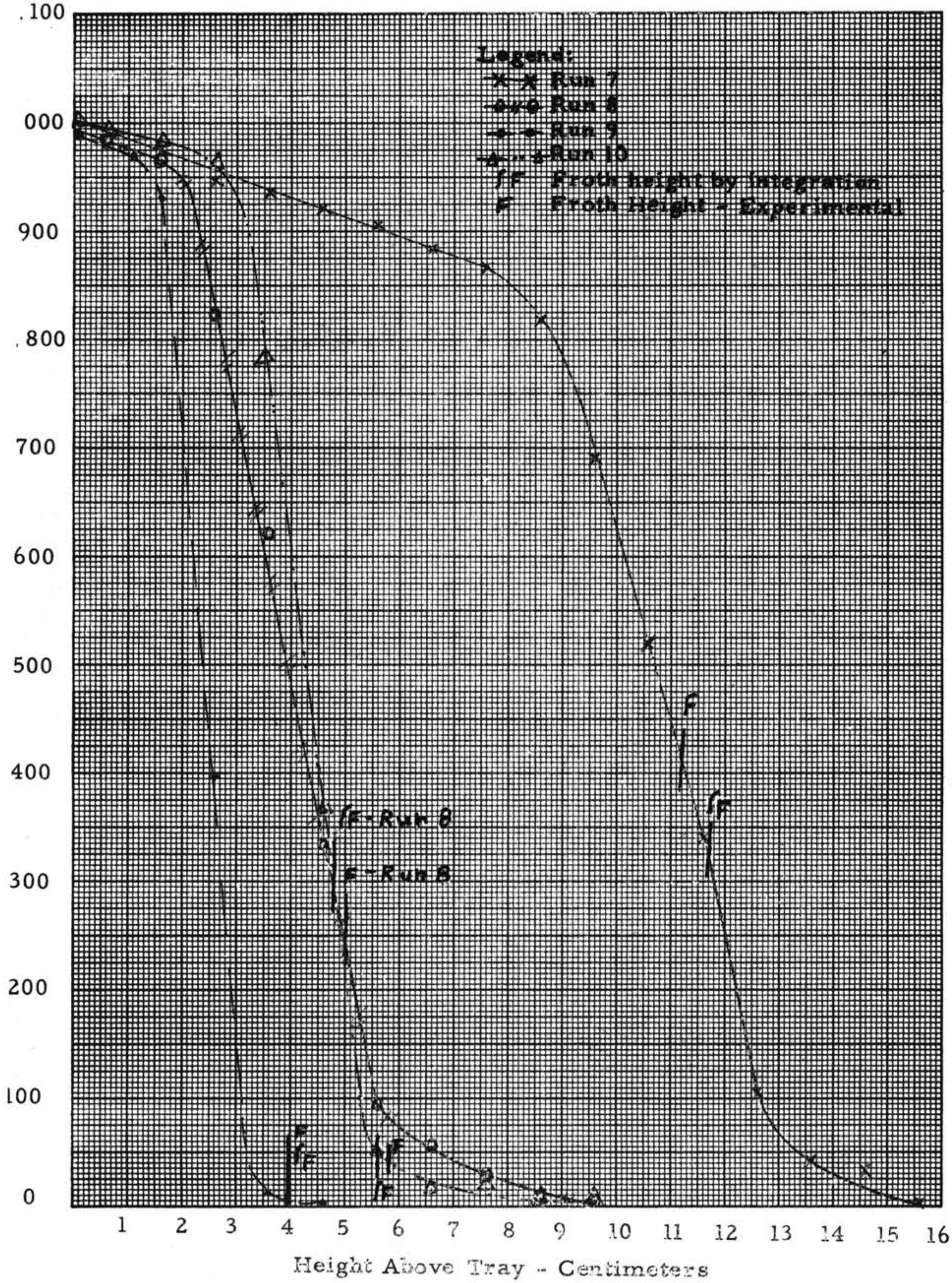

FIGURE 9

Density As A Function of Height Above Tray
Runs 7, 8, 9, and 10

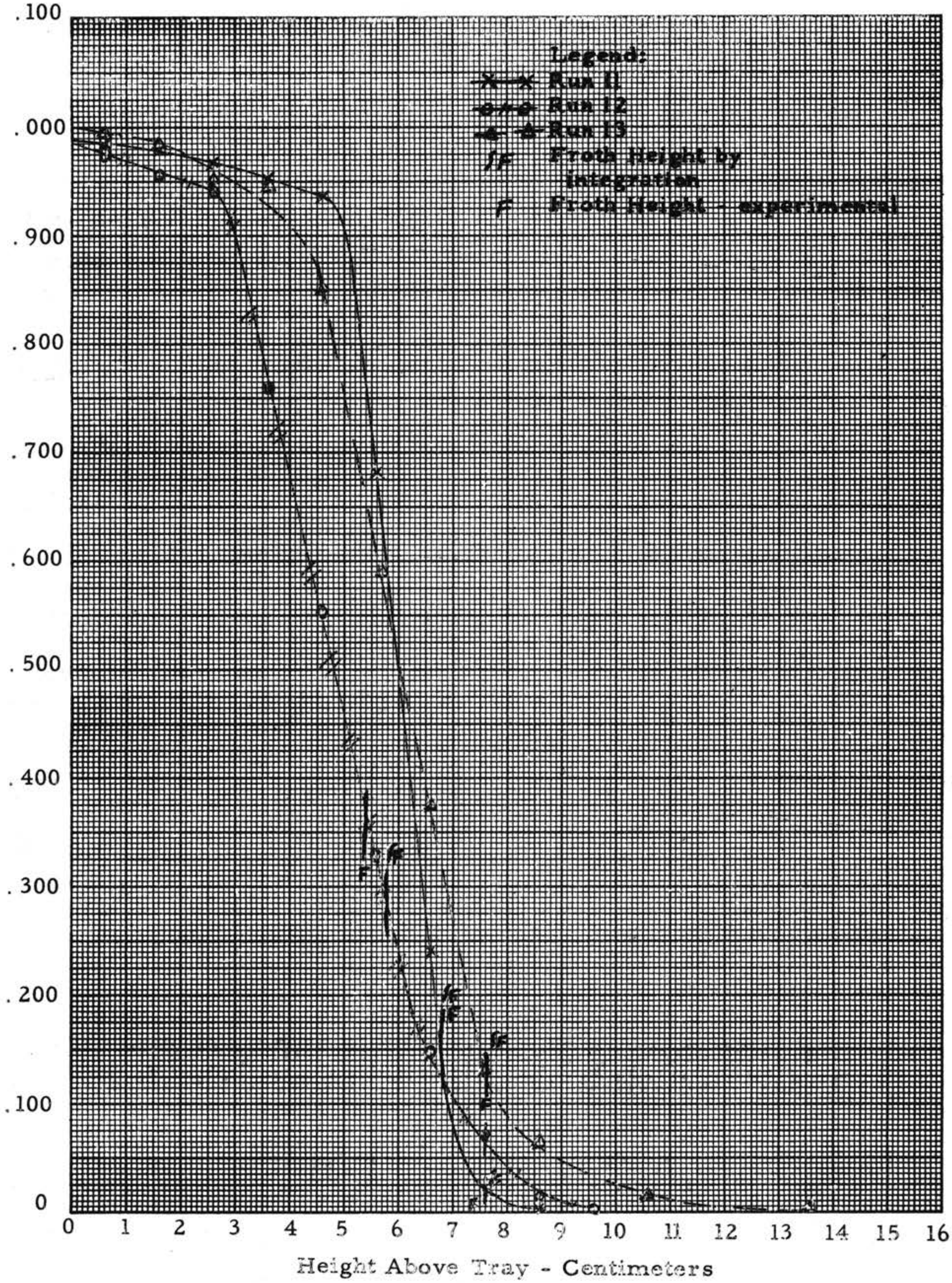

FIGURE 10

Density As A Function of Height Above Tray
Runs 11, 12, and 13

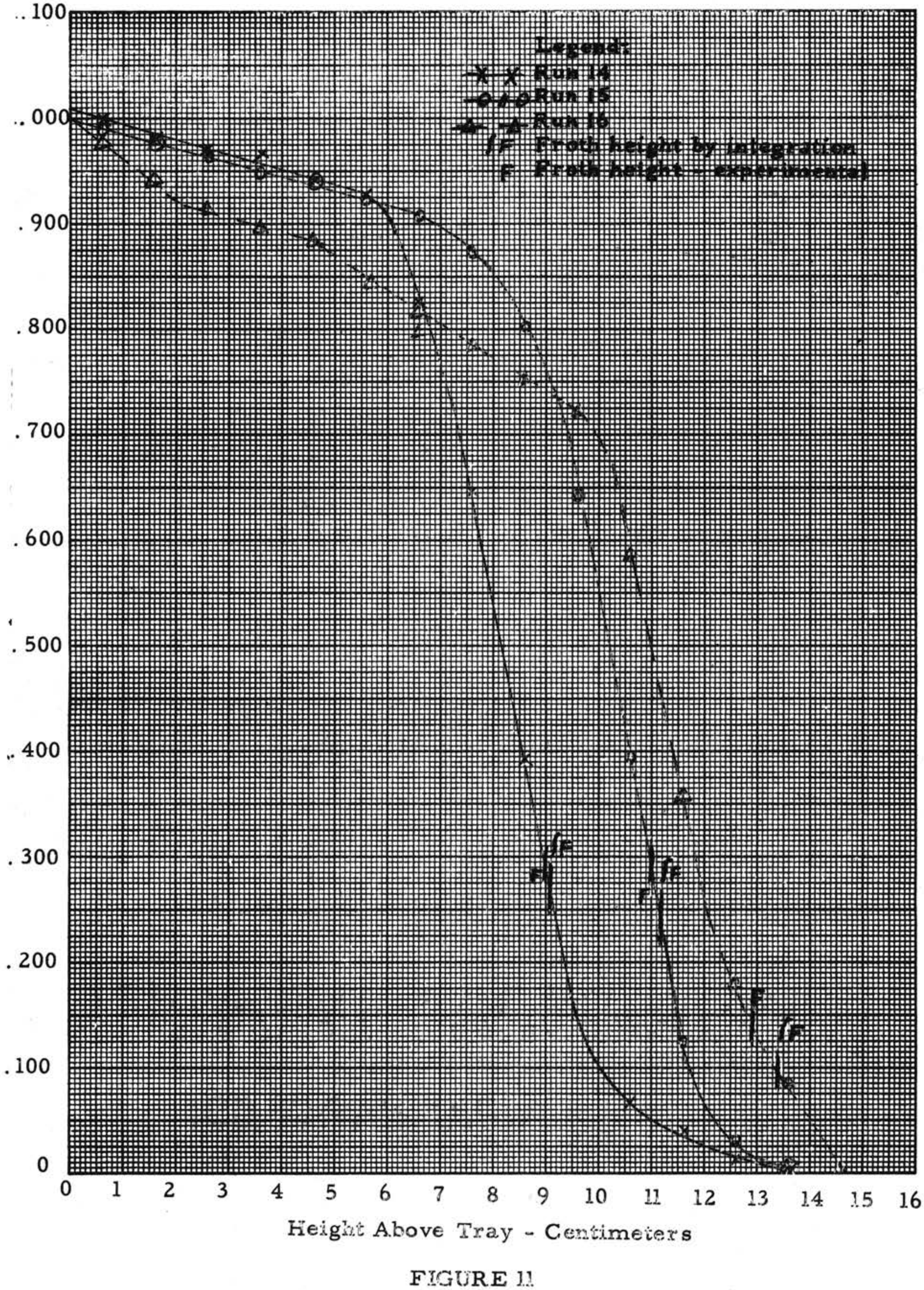

FIGURE 11

Density As A Function of Height Above Tray
Runs 14, 15, and 16

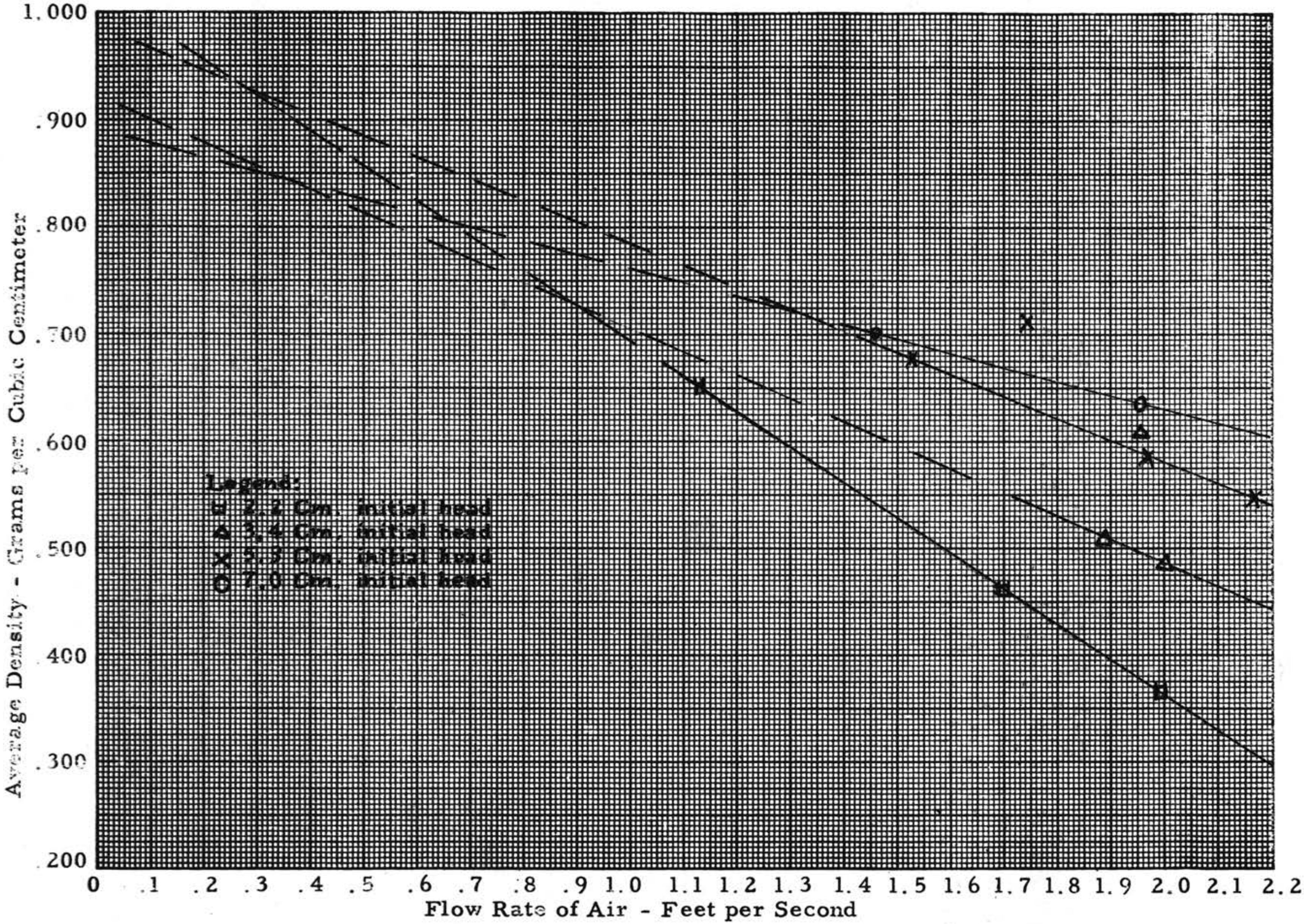

FIGURE 12
Average Densities As A Function of Flow Rate of Air

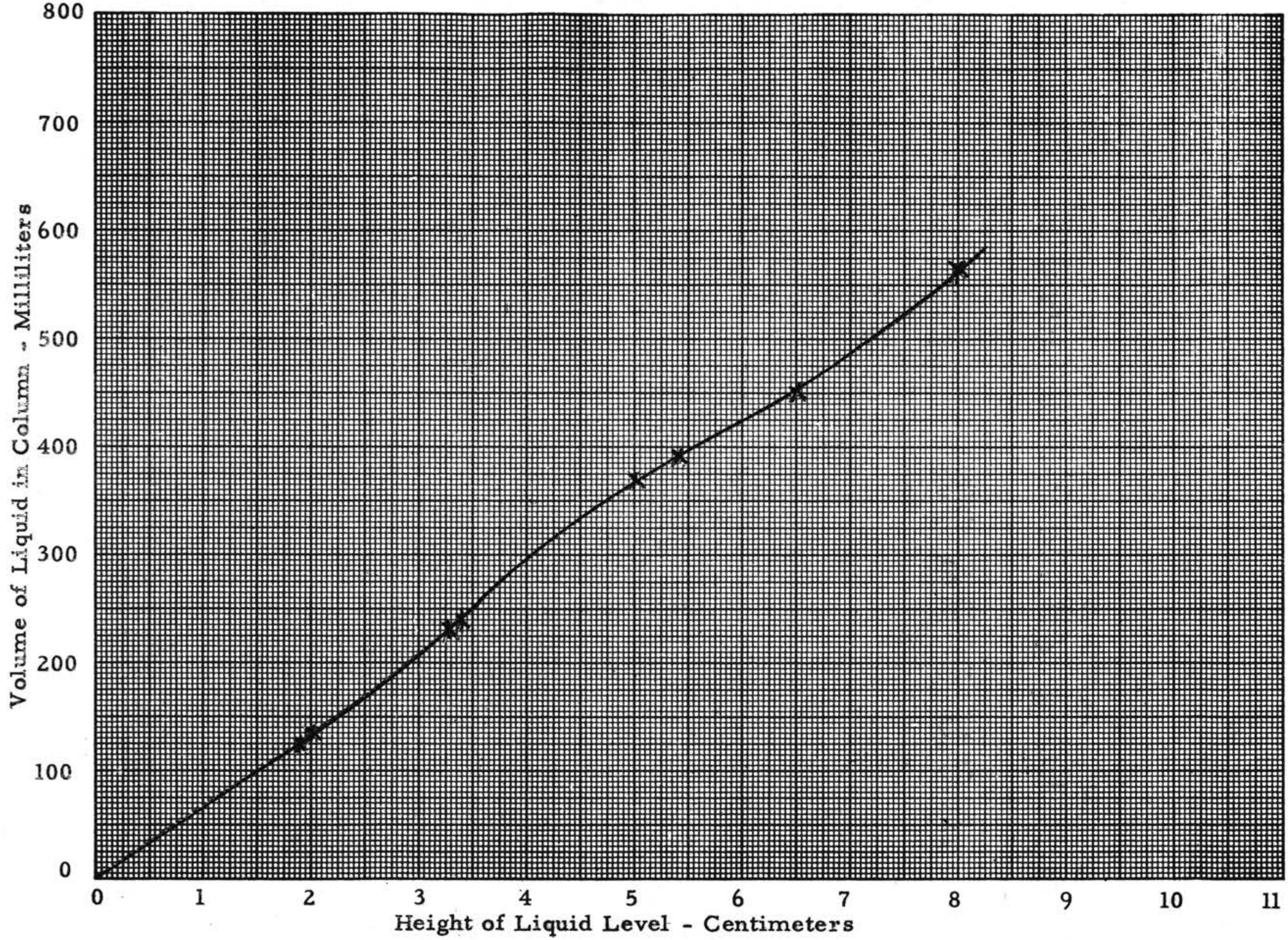

FIGURE 13
Volume of Fluid in Column As A Function of Height of Liquid Level On Tray

VITA

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